High Velocity New Product Development

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Abstract

Development processes often slow down or slip schedule because of poor management of the knowledge inventory being developed. Project managers schedule tasks with little regard for critical knowledge timing and capacity. Some subprojects can finish far ahead of others, resulting in knowledge that sits and depreciates until needed. By contrast in the area of Supply Chain Management, successful companies have learned to maximize the "velocity" of physical products and inventories, where timing and capacity are key. They understand that such inventories cost money to hold and can "rot", or lose value rapidly.

We show how lessons from Supply Chain Management can be applied to new product development processes to speed time to introduction. First, we view the project in terms of knowledge development rather than product development. Next we analyze the risks, capacity and timing of the "knowledge inventory" we are building. Postponement development is introduced as a means of increasing resources for the high-risk elements first, minimizing overall knowledge inventory and producing this knowledge just-in-time.

Development projects can be speeded and the resulting products can be much closer to customer needs using these concepts. Two case studies from Agilent Technologies will be used to illustrate the points.

Introduction

In the supply chain, physical inventories are risky, costing time and money to build and store. These inventories gain value as they move through the manufacturing process but, when stored or improperly routed, can also lose value rapidly (or "rot") because of obsolescence, changes, assembly mistakes, component flaws, etc. Excess inventory can greatly slow the "velocity" of products through the supply chain, bottlenecking capacity, increasing cycle times and exacerbating the risk.

By analogy, the "knowledge inventory" of a development program gains in value as it flows through the development process, but can also "rot" if it is stalled or not properly coordinated with other knowledge streams. For example, part of the team might develop a microprocessor-based controller in advance of other parts of the product. While this set of hardware and programming knowledge is waiting for the rest of the project to catch-up, the microprocessor could become obsolete, or the programmer might leave, or other factors could cause the controller to have to be redeveloped. Excess knowledge "work-in-progress" (too many projects occurring simultaneously) can also cause bottlenecks in critical development processes and services and greatly increase the development time and risk of the project[i].

Lean manufacturing and lean supply chain techniques have vastly improved manufacturing techniques in the last decade by minimizing risky inventory, moving stores as far upstream as practical, and using postponement techniques for customization. In design, the analogous practices are to develop the "riskiest" and longest lead-time knowledge inventory first ("upstream"), and to postpone low-risk, customized features and specifications until later in the project. Knowledge inventory is "risky" if the team does not know how long it will take to acquire, or has lower confidence that it can be adequately acquired. The following case studies illustrate these concepts:

<u>Case Study #1: An electro-optical modulator.</u>

At Agilent's Microwave Technology Center, engineers were developing a state-of-the-art electro-optical modulator chip for fiber optics communication test equipment. These devices, although demonstrated in universities and scientific labs, were not in production anywhere at the time. The modulator is a "chip" of the crystal lithium niobate a few centimeters on a side. Light enters one side of the chip though an optical fiber and exits the other side though another fiber. An electrical connection provides for the modulating signal.

The development team began to think about the streams of knowledge development required to produce a package of documented processes, supplies and skills needed to market, manufacture and deliver these chips to the "customers" – instrument producers. The team first did preliminary studies to assess the highest risk areas for this project. These areas were found to be:

1. The optical fiber alignment and attachment method
2. The reliability of the fiber connection

Surprisingly, the pattern of the optical waveguide on the chip was evaluated as much lower risk, even though this "masking" pattern was the subject of most previous research papers.

To move these risks upstream as far as possible, the team began experiments with aligning and attaching fibers to the chips with very simple (straight-through) waveguide patterns. As soon as any attachment was made, it was subject to rigorous environmental and strife testing – the team did not wait to see if modulation could be demonstrated with the masking patterns. It was only after the confidence became high from these experiments that the engineers began experimenting with more sophisticated waveguide and metalization patterns to demonstrate optical modulation. This strategy was counter to the prevailing project management practice, which was to approach the more "technically stimulating" part of the project first – achieving the high-speed optical modulation.

After about 12 months, the modulator team had demonstrated enough confidence and produced enough skills, tools and information to manufacture electro-optical modulators. Now it was time to begin the lower-risk, custom parts of the project – designing a modulator for a specific application, an Optical Network Analyzer. The specific waveguide pattern to achieve this performance was quickly developed and demonstrated by the team, using the very latest university and science lab research results, while the final specs for the analyzer were being established. The instrument was introduced close to original schedule and without problems from the modulator assembly. Other modulators with customized performance were produced very rapidly, and with great confidence, for other customers.

Analogy with Supply Chain Management

This case illustrates the main points of the article: a development team produces knowledge inventory. The knowledge inventory flows and builds through the development process, increasing confidence and decreasing risk. Like physical inventory, knowledge inventory takes time to build and carries cost and risk.

The figures below illustrate these concepts. Figure 1a. diagrams a "push" supply chain, typical of slower clockspeed industries and vertically integrated companies. Inventories of parts and work-in-progress are stored in many places so that all workcenters can be kept fully utilized. Following any one part or component through the many processes and queues shows that the lead-time can be very slow. Inventories in such supply chains can be very risky, rotting rapidly for myriad reasons. Long test and rework loops can further stretch cycle times. In Figure 1b, we illustrate a more modern supply chain. Suppliers provide parts "just-in-time" for manufacturing, minimizing inventories and maximizing the "velocity" of any part. Final variations in the

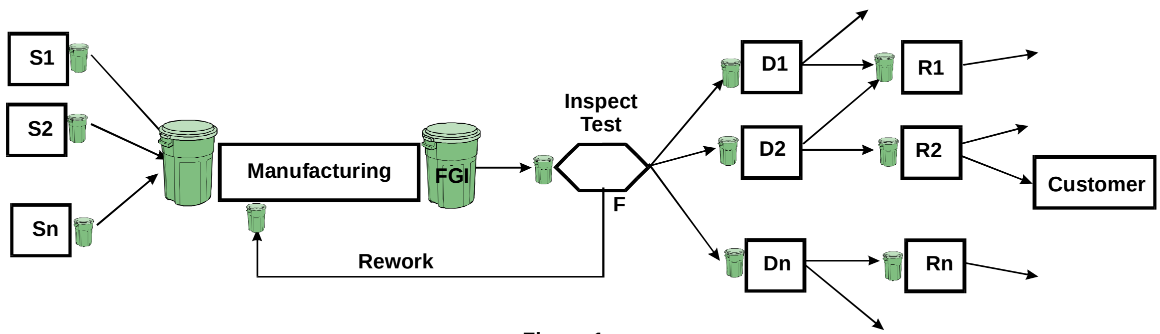


Figure 1a.

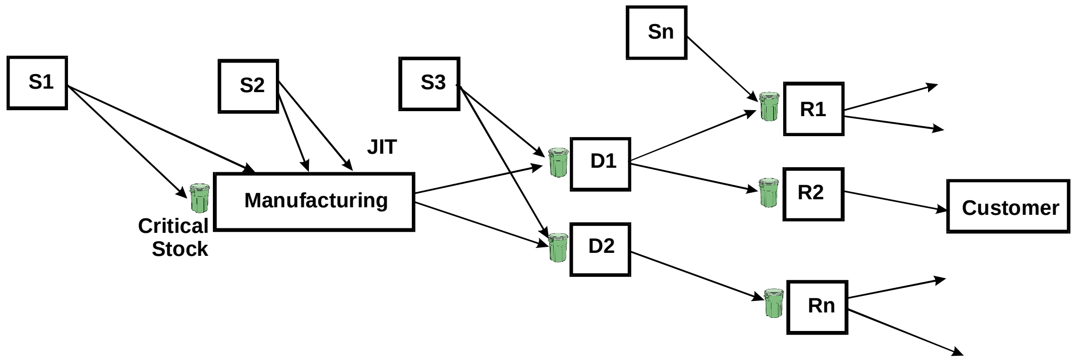


Figure 1b.

Inventory Stores or Buffers
Sx - Suppliers Dx - Distributors Rx - Retailers

product may be postponed and made by the Distributor or even by the Retailer to minimize inventories of multiple variations. Components traverse through the system faster than they can become obsolete, and flaws are discovered rapidly.

In Figure 2a, we illustrate a typical "push" development flow. In the product definition phase, a big investment is made in R&D and marketing to specify the product as fully as possible. This process can require a long time – a time which is not often even measured in the "time to market" calculation. The concept documents, market requirements document, reference specification, and potential technologies and suppliers represent the "knowledge inventory" at this point. The development project is usually planned as a parallel development of all modules of the product. Nearly all subprojects are started as soon as possible. Why? Perhaps because a careful risk analysis has not been done, so all parts are treated as being equally risky. Also, many project managers are rewarded for demonstrating "early success" by completing low-risk subprojects quickly.

Often the individual developers are working on multiple projects, and key resources and services are shared with other projects to maximize utilization. Knowledge inventory is built and "stored" until other subprojects are ready. This completed knowledge inventory can dissipate and rot before it is needed at the next integration level. The high-risk parts may not be tested until well into the project or prototype phase, causing long iteration loops. The books in the figure indicate storage points for knowledge inventory.

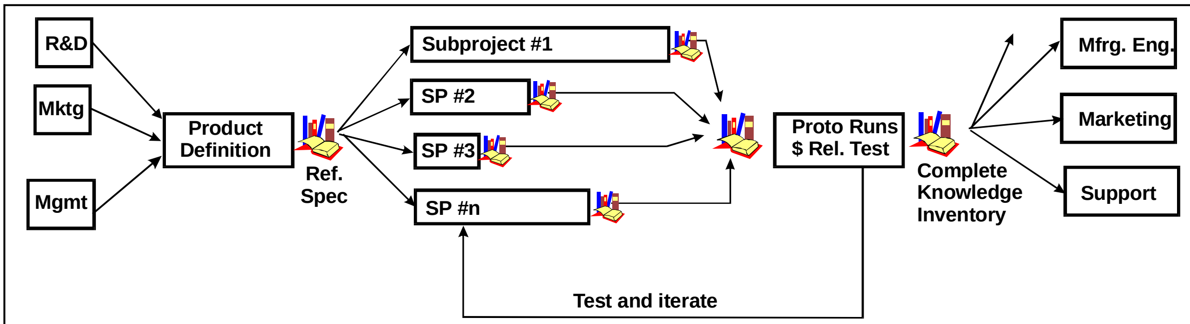


Figure 2a.

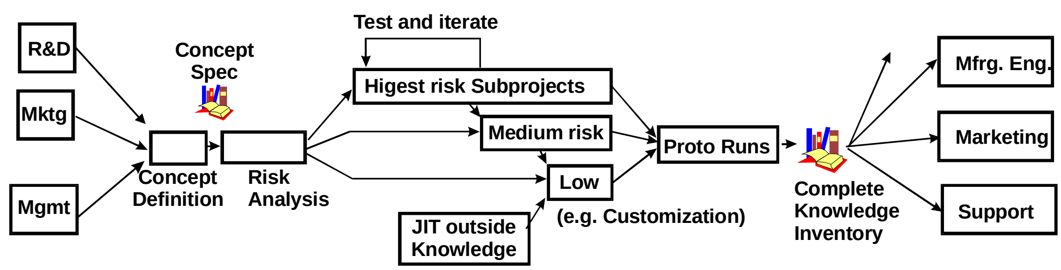


Figure 2b.

Figure 2b illustrates the "just-in-time" analogy for project management. First, the knowledge for the concept is collected from marketing, R&D and management. Ideally, a robust, market-driven product definition process will be employed to define this product concept, but detail specifications are not yet set. Next, a careful analysis is done to ascertain the highest-risk and longest lead-time elements of the project. Most of the project resources are initially dedicated to these knowledge development tasks, postponing many of the lower-risk studies. "Suppliers and subcontractors" of knowledge may be employed to add important knowledge elements, component information and documentation to the project where needed. The high-risk subprojects generate the most knowledge. Medium- and low-risk subprojects are postponed and started as late as possible so that the total knowledge package comes together at the same time. These lower-risk subprojects can also take into account the very latest "just-in-time" knowledge from the high-risk subprojects, suppliers, customers and other sources to minimize the integration risks.

In effective supply chains, the physical inventories are highly visible, tracked by finance and managed by inventory managers. It is the job of these people to minimize inventory and keep it moving. Likewise, the best development projects have some kind of knowledge inventory manager, specifically tracking documents and other knowledge repositories, and making sure it comes together with the right timing.

Postponement Design

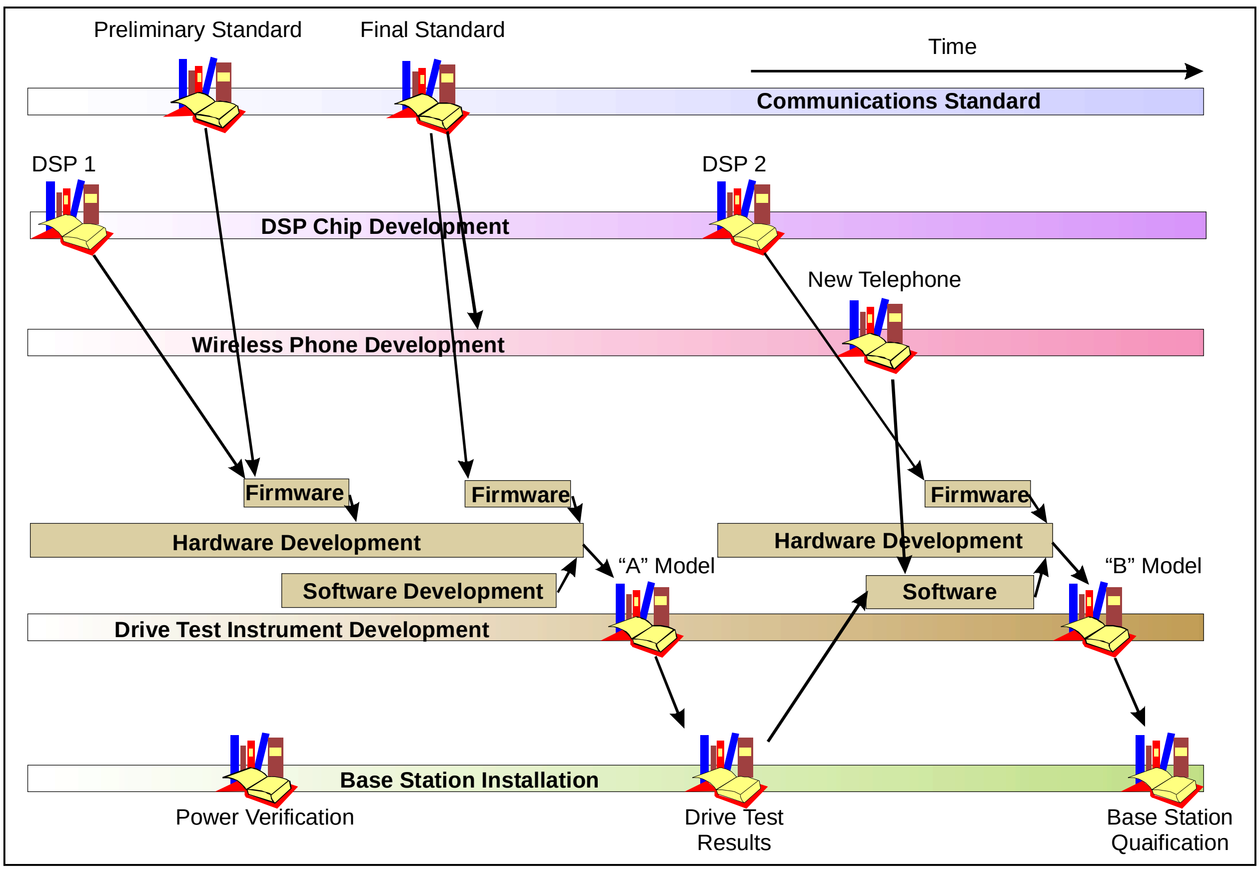
Postponement manufacturing is one of the cornerstones of modern supply chain management practice. Many of today's products offer variations, options and customized features. These variations cause difficulties for supply chain managers, who must anticipate needs for retailers and distributions centers. It is very expensive to provide all distributors and retailers with all combinations. Instead, most companies now provide distribution centers with the basic components. The distributors, the retailers or even sometimes the customers do the "final assembly". An example is personal computers, where distributors may assemble a system from choices of microprocessors, hard disk drives, etc. with very fast turnaround for customers.

The modulator case study illustrates an example of postponement design. The development team was able to "stock" an inventory of knowledge about how to build a reliable modulator, with processing techniques, packaging, and reliable waveguide attachments before deciding on an actual design spec. Concurrently, the "customer" (the instrument development team) was designing an instrument in need of a particular modulator specification. The modulator team was able to use already proven CAD techniques to rapidly produce the needed modulator information and to demonstrate a prototype and production capability.

<u>Case Study #2: A "Drive Test" system for measuring and validating wireless telephone base station cells.</u>

In many cases, manufacturers no longer have the luxury of waiting until the problem is completely specified before developing a solution. One such case is the Drive Test system from Agilent Technologies, which measures the coverage, effectiveness and quality of wireless phone base stations – or "cells". Agilent faces the challenge of bringing together three different sets of rapidly changing knowledge inventories in order to provide a valuable test solution for cell manufacturers and operators. New and existing wireless communication standards are emerging and growing rapidly, standards such as GSM, TDMA (NADC), CDMA (IS95), 3GPP, 3GPP2, etc.

The timing problem is illustrated in Figure 3. In order to capitalize on a new communication standard, service providers must install a network of base station cells rapidly – as soon as the new phones are available. Base stations are large racks of equipment spread throughout a service region, representing a very large capital investment for the service provider. They receive no income from this investment until the cells are fully working and commissioned. The Drive Test system is designed to be driven around the cell region and measure important parameters and signal handling quality of the base stations.



The riskiest and longest lead-time part of developing such a test solution is the system hardware, including radio- and microwave-frequency components, high-speed digital components and rugged mechanical parts. Because of the long lead time, the designers must start on these modules before the new communication standard, the phones, or the bases stations are available. A key component in the test system, the digital signal processing (DSP) chip, also evolves rapidly and the latest one may not yet be available either.

Using the lessons of postponement design, the Agilent project manager concentrates most of his available resources on developing the RF, high-speed digital and mechanical parts of the system. He designs using the latest DSP chip (DSP1), and only a preliminary version of the telephone communication standard is available. He postpones the actual programming of the DSP chip until as late as possible because this coding requires resources, but is low risk. He also considers the instrument software to be low-risk, so he waits, using those resources to tackle higher-risk subprojects. When the software programming does begin, the team uses the latest knowledge inventory from the customer and from the communication standards committee. When the communication standard is finalized, it is coded rapidly into the system.

At this point, wireless phones still may not be available. Nonetheless, Agilent releases an "A-model" of the test system for purchase and use by the service provider. These systems can detect and measure many useful base station parameters, including testing for radio-frequency interference and the fidelity of long coding sequences. These systems are invaluable in placing and tuning the base station cells.

As the phones and latest DSP chip (DSP2) become available, Agilent once again employs postponement techniques to rapidly develop the "B-model". This model includes all coding and protocols and a sample wireless telephone so that the quality of real calls can be monitored. The custom knowledge from using the A-model are used in the B-model development. The service provider can upgrade "A" models or purchase the new "B" models separately.

This case illustrates how the timing of knowledge inventories from different, distributed sources can come together to create value for the service provide and for the instrument manufacturer.

Intelligence, Guts, Discipline And Faith

Most project managers schedule projects using critical-path analysis tools with the "earliest possible" start date in mind. This tendency stems from deep-rooted fear that all parts of a project may be high risk, so one should try to find as many problems as possible as early as possible. In addition, there is a fundamental belief that projects will get done faster and better if everyone's utilization is maximized – everyone should be busy. As Reinertsen[ii] points out, these assumptions cause several effects that reinforce each other in a spiral of problems and slippage:

1. Lead times and cycle times are longer because all of the resources and services build queues of work.
2. Engineer "shotgun" designs (try multiple variations at once) to try to get more knowledge out of the slower processes, adding more "work-in-progress" to the bottlenecks.
3. The less-risky projects sap resources from the higher-risk ones, slowing everything down.

Leading a "lean" and rapid development project requires intelligence, guts, discipline and faith. Intelligence is needed up-front to carefully analyze the real risks in the project. Guts and discipline are required to assign most resources to mitigating these risks, almost ignoring the low-risk bits for the time being. Finally, a project manager must have faith that the low-risk parts really are that, or at least her lean design team can solve that unexpected problem rapidly.

The risk can be lowered in a number of ways, including re-use of proven subassemblies, rapid prototyping, and using well-proven CAD models.

Summary

The job of a development team is to build a "knowledge" product, consisting of the complete set of information and skills needed to market, manufacture and deliver a physical product. The design chain can be viewed as a collection of "knowledge inventory" streams that are building in value and converging in time to form the final knowledge product. The timing and flow of these knowledge inventories is very important in minimizing the development time. Too much "work-in-progress" can cause severe bottlenecks, slowing the project to a halt. The project manager can run a "lean" development chain by minimizing the project work and scheduling the knowledge inventory to arrive at the right time. The highest risk investigations should be heavily resourced at the beginning, with low-risk projects and customization postponed until late in the process. Just as in running a lean manufacturing line, this kind of project management requires intelligence, guts, discipline and faith. A case study from two successful projects in Agilent Technologies illustrated these concepts.

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[i] Adler, Paul S., et al; Getting the Most out of Your Product Development Process; Harvard Business Review, March-April 1996, pp. 134-152

[ii] Reinertsen, Don; Managing the Design Factory – A Product Developer's Toolkit; The Free Press, NY 1997.